FISHERY RESEARCH

KOOTENAI RIVER WHITE STURGEON INVESTIGATION

KOOTENAI RIVER WHITE STURGEON SPAWNING AND RECRUITMENT EVALUATION

ANNUAL PROGRESS REPORT
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Prepared by:

Vaughn L. Paragamian, Principal Fisheries Research Biologist

Gretchen Kruse, Senior Fisheries Technician

and

Virginia Wakkinen, Fisheries Technician

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Project Progress Report

1999 Annual Report

By

Vaughn L. Paragamian, Principal Fisheries Research Biologist
Gretchen Kruse, Senior Fisheries Technician
and
Virginia Wakkinen, Fisheries Technician

Idaho Department of Fish and Game
600 South Walnut Street
P.O. Box 25
Boise, ID 83707

To

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABSTRACT

Sampling for adult Kootenai River white sturgeon *Acipenser transmontanus* began in March and continued through April 1999. Forty-six adult sturgeon were captured with 4,091 hours of angling and set-lining effort, while an additional three adult sturgeon were captured during gillnetting for juveniles. Flows for Kootenai River white sturgeon spawning were expected to be high because the snow pack in the basin was estimated at 130% of normal, but runoff came very slowly. Discharge from Libby Dam from mid-March through mid-June was maintained at 113 m^3/s (4,000 cfs). Flows in the Kootenai River at Bonners Ferry during early April, including local inflow, were 227-255 m^3/s (8,000-9,000 cfs) but increased gradually in late April to a peak of 657 m^3/s (23,200 cfs). Flows subsided in early May to about 340 m^3/s (12,000 cfs), but rose to 1,031 m^3/s (36,370 cfs) by May 26 because of local runoff, and white sturgeon began spawning. However, flows subsided again to 373 m^3/s (13,200 cfs) June 11, 1999 and some female white sturgeon with transmitters began leaving the spawning reach. Water temperature ranged from about 8°C to 10°C (45°F to 50°F) during these two weeks. On June 13 (two weeks after sturgeon began spawning), spawning and incubation flows from Libby Dam began. The flow was brought up to 1,136 m^3/s (40,100 cfs) and temperature rose to about 11°C (52°F). We sampled for 3,387 mat days (one mat day is a single 24 h set) with artificial substrate mats and captured 184 white sturgeon eggs. The Middle Shorty's Island reach (river kilometer [rkm] 229.6 - 231.5) produced the most eggs (144), with 388 mat days of effort; the Refuge section (rkm 234.8 to 237.5) with 616 mat days of effort produced 23 eggs; and the Lower Shorty's section produced 19 eggs with 548 days of mat effort. No eggs were collected above the Refuge section (>rkm 240.5) with 988 mat days of effort. We do not believe flows for sturgeon spawning in 1999 were very timely for adequate spawning. Most spawning is thought to have occurred before the spawning flows, when 66% of the spawning events and 87% of the eggs were collected. Recommendations for the 2000 spawning season include coordinating the flow test with sturgeon spawning behavior and targeting river temperatures of 8°C to 10°C (46°F to -50°F) without jeopardizing sturgeon migration or spawning behavior. Flows from Libby Dam during white sturgeon spawning, egg development, and early rearing should be between 708 m^3/s (25,000 cfs) and 765 m^3/s (27,000 cfs) for 42 days. This would provide flows of about 1,130 m^3/s (40,000 cfs) at Bonners Ferry. We also recommend the release of hatchery cultured larval white sturgeon to help resolve the issue of an egg to age-2+ survival "bottleneck" and aid in the evaluation of our sampling gear.

Authors:

Vaughn L. Paragamian
Principal Fisheries Research Biologist

Gretchen Kruse
Sr. Fisheries Technician

Virginia Wakkinen
Fisheries Technician

OBJECTIVE

1. Determine environmental requirements for adequate spawning and recruitment of white sturgeon *Acipenser transmontanus*.

STUDY SITE

The Kootenai River originates in Kootenay National Park, British Columbia (BC). The river flows south into Montana and turns northwest at Jennings, the site of Libby Dam, at river kilometer (rkm) 352.4 (Figure 1). Kootenai Falls, 40 km (24.8 mi) below Libby Dam, is thought to be an impassable barrier to sturgeon. As the river flows through the northeast corner of Idaho, there is a gradient transition at Bonners Ferry. Upriver from Bonners Ferry the channel has an average gradient of 0.6 m/km (3.15 ft/mi) and the velocities are often higher than 0.8 m/s (2.6 ft/s). Downriver from Bonners Ferry the river slows, with velocities usually less than 0.4 m/s (1.3 ft/s). The average gradient is 0.02 m/km (0.1 ft/mi), the channel deepens, and the river meanders north through the Kootenai River Valley. The river returns to BC at rkm 170 and enters the South Arm of Kootenay Lake at rkm 120. The river leaves the lake though the West Arm of Kootenay Lake to its confluence with the Columbia River at Castlegar, BC. A natural barrier at Bonnington Falls (now a series of four dams) has isolated the Kootenai River white sturgeon from other populations in the Columbia River basin for approximately 10,000 years (Northcote 1973). The basin drains an area of 49,987 km^2 (19,300 mi^2) (Bonde and Bush 1975). Regulation of the Kootenai River with Libby Dam changed the natural hydrograph of the river. Post-Libby Dam flows during spring were up to four times higher (Figure 2). However, since 1991 mitigative flows have further changed the Kootenai River spring hydrograph to accommodate white sturgeon spawning (Figure 2).

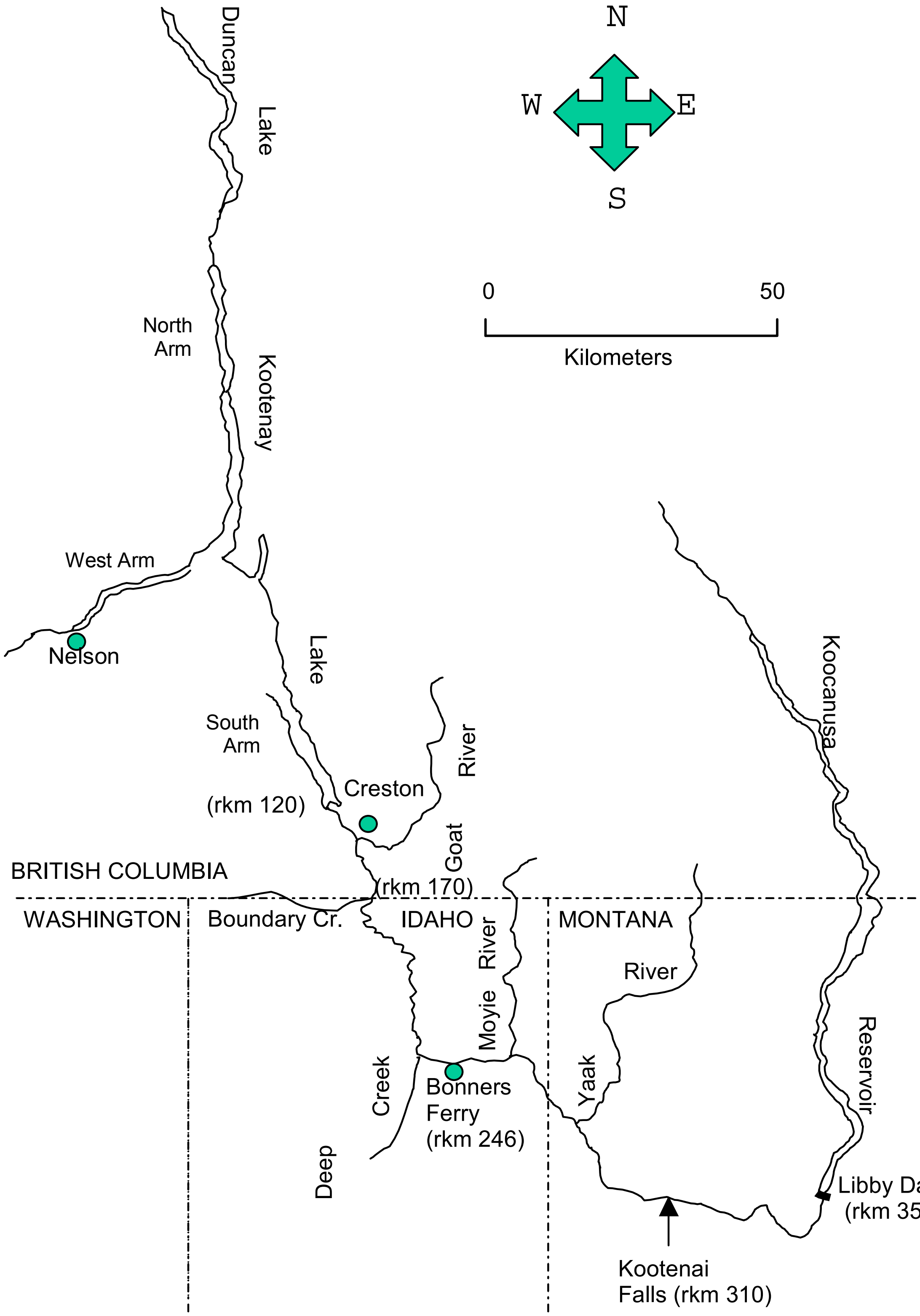

Figure 1. Location of the Kootenai River, Kootenay Lake, Lake Koocanusa, and major tributaries. The river distances from the northernmost reach of Kootenay Lake are in kilometers (rkm) and are indicated at important access points.

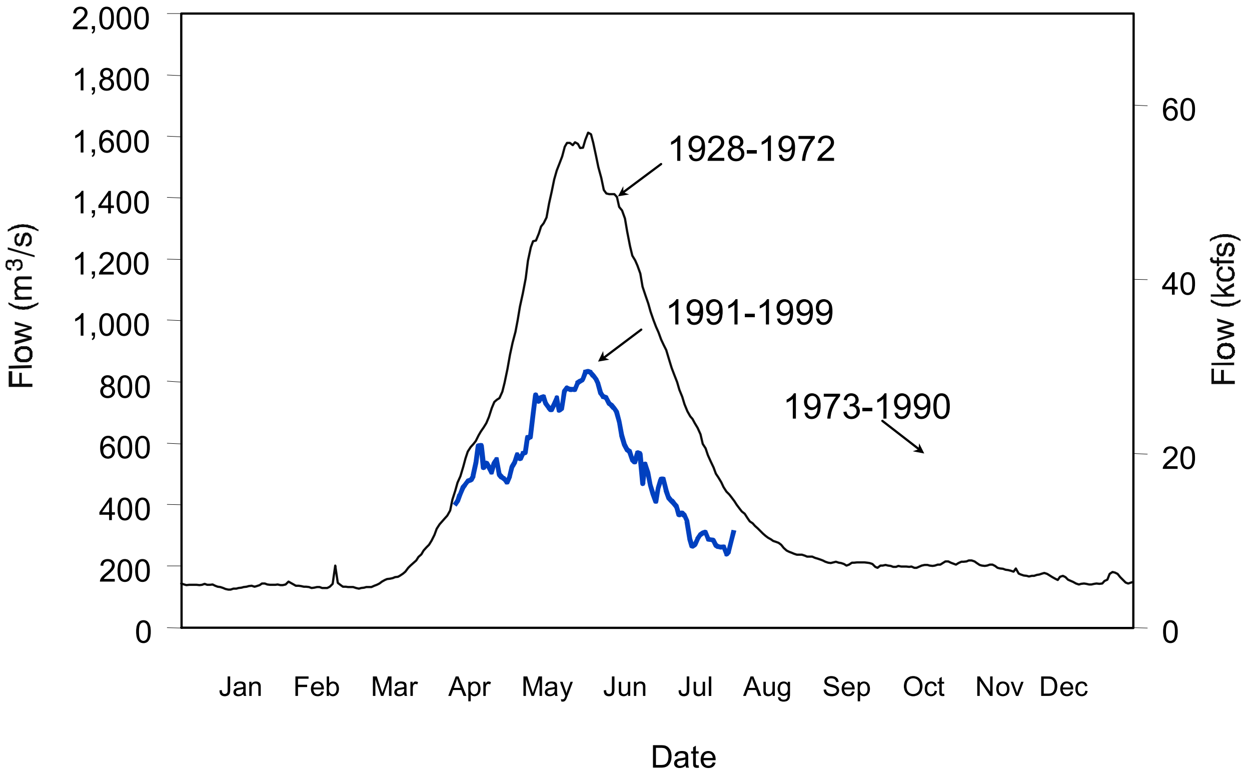

Figure 2. Mean daily flow patterns in the Kootenai River at Bonners Ferry, Idaho from 1928-1972 (pre-Libby Dam), 1973-1990 (post-Libby Dam), and 1991-1999 (post-Libby Dam with augmented flows).

METHODS

Discharge, Water Temperature, and Secchi Measurements

Kootenai River discharge and water temperature data at Bonners Ferry and discharge from Libby Dam were obtained from the US Army Corps of Engineers (USACE). The US Fish and Wildlife Service (USFWS) and USACE established operational guidelines for Libby Dam for the 1999 Kootenai River white sturgeon spawning season.

Secchi disc measurements were made during egg mat sampling to provide a measure of turbidity during spawning. Measurements were made at rkm 229.8, 240.0, and 244.5. Daily measurements were averaged.

Adult White Sturgeon Sampling

Adult white sturgeon were captured with rod and reel or set lines from March 1, 1999 to March 25, 1999 as described in Paragamian et al. (1996). Adult white sturgeon expected to spawn in 1999 were tagged with radio and sonic tags and monitored to determine movements during the spawning season (Paragamian et al. 1996).

Adult White Sturgeon Telemetry

Movement and migration of adult white sturgeon fitted with sonic and radio transmitters were monitored monthly from the Kootenai River at Bonners Ferry into the river's delta at Kootenay Lake. The main objective was to locate late vitellogenic females and reproductive males migrating upstream to staging and spawning reaches. Each transmitter location was recorded to the nearest 0.1 rkm (0.061 mi). Effort required to monitor sturgeon movement and activity varied with season. Less effort was required during winter months when most fish moved less frequently than in spring and autumn. Increased activity of tagged fish during the prespawning and spawning seasons required more frequent monitoring. Reaches above Copeland, Idaho (Figure 1) were monitored more intensively than downriver or Kootenay Lake, especially during the prespawning and spawning periods when mature sturgeon moved upstream.

Fixed-receiver Telemetry

Three fixed receivers were stationed between rkm 230.3 and 244.5. Site 1 was situated furthest downriver at mid-Shorty's Island (rkm 230.3). This downriver position was selected to detect fish movements into the Shorty's Island spawning reach (rkm 229.9 to 231.0). Site 2 was located at the Kootenai National Wildlife Refuge (237.5). Site 3 was located just upriver from Ambush Rock (244.5) on the south side of the Kootenai River at the end of a straight reach of river. This new upriver location was chosen in an effort to detect fish movements above Ambush Rock (rkm 244.4), eliminate background noise problems experienced at the previous upriver site on the north side of the Kootenai River in 1998, and avoid vandalism that occurred at the previous southside site in 1997 and 1998.

Each fixed-receiver station consisted of a scanning receiver (Advanced Telemetry Systems [ATS] model R2100), data logger (ATS model DCCII), 3-element Yagi antenna, and a 12-volt deep-cycle battery to operate the system. Antennae were mounted on 1.8 m (6 ft) metal fence posts, horizontal to the river and affording a clear 180-degree view of the river. Selected sites were all on straight reaches to facilitate reception of the 24 radio frequencies of potential male and female spawners programmed into the receivers. Data loggers were set to record only those signals matching the specific pulse rates (pulse per minute) of the tagged white sturgeon. A pattern-matching option was also selected to verify signals. A test radio tag was used to verify detection range and strength at each site.

Fixed-wing Telemetry

Two loop antennas were mounted on the wing struts of a Cessna 182 for fixed-wing aerial telemetry. Weekly flights followed a route downriver from Bonners Ferry to Kootenay Lake at an altitude of 500 to 1000 feet above the river and at speeds of 60 to 80 knots. Up to 13 preset radio frequencies of potential spawners were cycled through an ATS model R2100 scanning receiver and deleted as fish were detected. The frequency cycling rate was 2 to 4 seconds to facilitate maximum numbers of fish cycled (13) without sacrificing detection range.

Artificial Substrate Mat Sampling

White sturgeon spawning was documented with artificial substrate mats (McCabe and Beckman 1990). Adult white sturgeon densities were classified as high, medium, and low, based on numbers of observations of sonic- and radio-tagged fish. These classifications were based on observations from previous years: high—sturgeon were frequently located, medium—sturgeon were occasionally located, and low—sturgeon were seldom located (Paragamian et al. 1997). Egg mat densities in the spawning area were then based on general densities of monitored sturgeon in previous years. The length of the spawning reach was marked along the shoreline with flag material at each 0.1 km increment. We set an average of 19 mats/1.0 km (30 mats/mi) in the high-density sections (25 mats), an average of 1.05 mats/1.0 km (16 mats/mi) in the medium density sections (21 mats), and an average of 0.16 mats/1.0 km (0.25 mats/mi) in the low-density sections (24 mats). A 1 rkm reach from rkm 230-231 was not sampled, because it was a broodstock collection reach for the Kootenai Tribe of Idaho (KTOI). Some of the high and medium sites were sampled with two mats. The sites that were sampled with two mats were chosen randomly from all high or medium density sites.

Experimental Drift Nets

To help determine the vertical location of white sturgeon spawning in the water column, three 61 cm (24 in) diameter nets were suspended by chain and connected to a PVC pontoon. Nets were suspended at different levels: within a meter of the surface and at 5 and 10 m depth (16.4 to 32.8 ft). An anchor was suspended from the front of the pontoon to hold the net assembly in the river channel, and buoys were attached to the pontoon for additional flotation. One net assembly was deployed at rkm 235.0 and a second at rkm 230.8. Nets were deployed and checked daily to collect drifting larval fish, eggs, eggshells, and invertebrates.

Larval Sturgeon Sampling

We used surface- and midwater-paired half-meter net tows, bottom-towed D-rings, and benthic trawling to search for larval white sturgeon in the Kootenai River. We used two techniques for paired half-meter net sampling. Nets were towed upstream against the current during daylight and dusk hours. Tows were made at randomly selected locations between rkm 170 and rkm 240.

Juvenile White Sturgeon Sampling

Weighted multifilament gill nets with 2.5 to 5 cm (1-2 in) bar mesh and benthic trawls were used to sample juvenile and young-of-the-year (YOY) sturgeon (Paragamian et al. 1996; Fredericks and Fleck 1996). Gill net and benthic trawl sampling were completed at randomly selected locations between rkm 170 and rkm 236. Gill nets were set during the day and checked every hour. Juvenile sturgeon were processed using methods cited in Paragamian et al. (1996).

Benthic trawls were carried out at randomly selected locations in the Kootenai River (rkm 170 through 240). The trawl was towed downstream with the current, and sampling was performed during daylight hours from July through August 1999. The benthic trawl provided the opportunity to sample the bottom of the river with gear that would be selective for YOY and juvenile sturgeon.

Juvenile White Sturgeon Food Habits

The food habits of hatchery white sturgeon in the Kootenai River were studied by examining the stomach contents of fish recaptured during juvenile sampling. Only age-4 hatchery white sturgeon (1995 year-class) were used for food habit analysis. The sacrifice of up to 25 hatchery white sturgeon was authorized in our Section 10 Permit. All fish selected for food habits were weighed and measured (TL and FL). An incision was made in the abdominal wall to ensure preservation of the stomach and its contents, and then the fish was placed in a quart jar containing formalin. The date and location of the collection was noted. The stomach contents were identified to genus (if possible), enumerated, and dry weighed after drying with a Cole Palmer model 05012-10 dryer.

Age and Growth of White Sturgeon

Ages of adult and juvenile white sturgeon were determined by pectoral fin ray analysis (Marcuson et al. 1995, Paragamian et al. 1996). Two thin sections were sliced from each fin ray (0.79 and 0.95 mm) using a Buehler Diamond Wafering Blade. Thin sections were mounted on microscope slides and viewed with Optical Pattern Recognition System (OPRS) Data Acquisition Software. One age was recorded for each thin section, and if two different ages were determined, the oldest was accepted. Age information was used to determine year class structure.

Contaminants Analysis

Ovarian tissue was biopsied from stage-2 through stage-4 female sturgeon and collected from broodstock females at the KTOI hatchery. Ovarian tissue and eggs were analyzed for metal, organochlorine pesticide, and arochlor PCB residues. Results were compared with available ovarian tissue contaminant burden data collected from Kootenai River white sturgeon in 1989-1991 (Apperson and Wakkinen 1992). Mature stage-4 eggs were taken during spawning from female sturgeon used as broodstock at the KTOI hatchery. Egg size from each female was measured as numbers of eggs per ml. Blood plasma steroid levels were also measured in biopsied females (Fitzpatrick 1996). Surface water and river-bottom substrate samples were collected at eight sites in the lower Kootenai River between rkm 205 and rkm 244.5 during mid-June 1999. Non-parametric analyses were applied to determine potential relationships and significant differences between the aforementioned parameters, age, length, and developmental stage of the females ($\alpha = 0.05$).

Sturgeon embryos were reared in three different mediums at the KTOI hatchery to determine contaminant uptake from exposure to the mediums during development. Eggs from one female were fertilized with sperm from one male. Each of the three groups was broken into eight subsamples. Group 1 was de-adhesed with suspended solids from the river water column and reared in unfiltered river water; group 2 was de-adhesed with Fuller's Earth and reared in filtered river water; group 3 was de-adhesed with river-bottom sediment and reared in filtered river water. Dead and fungus-coated embryos were removed daily. At the end of 13 days, all remaining embryos and larvae were removed from the jars, combined with prior mortalities from prospective groups, and frozen for chemical analysis. Significant differences between groups were determined with the non-parametric Kruskall-Wallace and Mann-Whitney tests. Correlations between contaminant concentrations and mortalities were determined with Spearman's rank correlation analysis. Significance was set at $\alpha = 0.05$.

Twenty-four juvenile age-4 hatchery white sturgeon (released in 1997) were captured in gillnets for DNA adjunct formation as well as liver lesion, acetylcholinesterase, and tissue residue analysis. Blood was drawn from the caudal vein of live fish. Fish were then dispatched and dissected to remove the liver and brain. Whole body tissues were shipped to a lab for analysis of metal, organochlorine pesticide, arochlor PCB, organophosphate, and carbamate pesticide analysis. Livers were preserved with Davidson's solution and bioassayed for lesions. Juvenile sturgeon used for this study were the same individuals collected for food habit analysis.

Egg Incubation and Temperature Experiment

We studied the development rate of Kootenai River white sturgeon eggs at 9.5°C. Applying these data and that of previously determined development rates at 12°C, 14°C, 16°C, and 18°C, Kootenai River white sturgeon eggs could be staged to more precisely estimate spawning events. Previously, sturgeon egg staging had been based on temperature and stages of white sturgeon from the Sacramento River (Beer 1981).

The experiment took place at the KTOI Hatchery. Approximately 20,000 fertilized white sturgeon eggs of one family were split into two lots and placed into McDonald jars. Filtered and UV-treated river water was chilled to 9.5°C and circulated through the McDonald jars. Temperature was continuously maintained. At specified times, usually every hour, ten eggs from each jar were randomly extracted and placed in vials of formalin. This experiment continued until most of the eggs had hatched. Eggs were to be subsequently staged by personnel of the Biological Services Division of the US Geological Survey (USGS).

RESULTS

Discharge, Temperature, and Secchi Measurements

Flows for white sturgeon spawning in 1999 were expected to be high, because the snowpack in the basin was estimated at 130% of normal, and local inflows were expected to be very high, <1,417 m^3/s (50,000 cfs) (conversions to cfs are rounded to hundreds). Libby Dam discharge from mid-March through mid-June was maintained at 113 m^3/s (4,000 cfs). Flows in the Kootenai River at Bonners Ferry during early April included local inflow and ranged between 227-255 m^3/s (8,000-9,000 cfs) (Figure 3). Flows gradually increased in late April and resulted in a peak of 657 m^3/s (23,200 cfs) (Figure 3). Flows subsided in early May to about 340 m^3/s (12,000 cfs) but rose to 1,031 m^3/s (36,370 cfs) by May 26 because of local runoff. Discharge subsided again to 373 m^3/s (13,200 cfs) June 11, 1999. Water temperature ranged from about 8°C to 10°C (45°F to 50°F) from May through early June (Figure 3). Spawning and incubation flows from Libby Dam began on June 13 (two weeks after sturgeon began spawning), and flow at Bonners Ferry was brought up to 1,136 m^3/s (40,100 cfs). During spawning flows, temperatures oscillated between 10°C and 12.5°C (50°F to 54.5°F). Flow gradually subsided at Bonners Ferry by June 20 and was steady at 765-850 m^3/s (27,000-30,000 cfs) through July 6 before dropping further, while temperature remained between 11°C and 12°C (51.8°F to 53.6°F).

We measured turbidity on 30 days for 90 measurements at the three sites from May 13 through June 26 (Figure 4). Secchi measurements averaged 1.52 m, SD = 0.68 m (4.99 ft, SD = 2.25 ft) and ranged from 0.30 m (0.98 ft) to 3.20 m (10.50 ft).

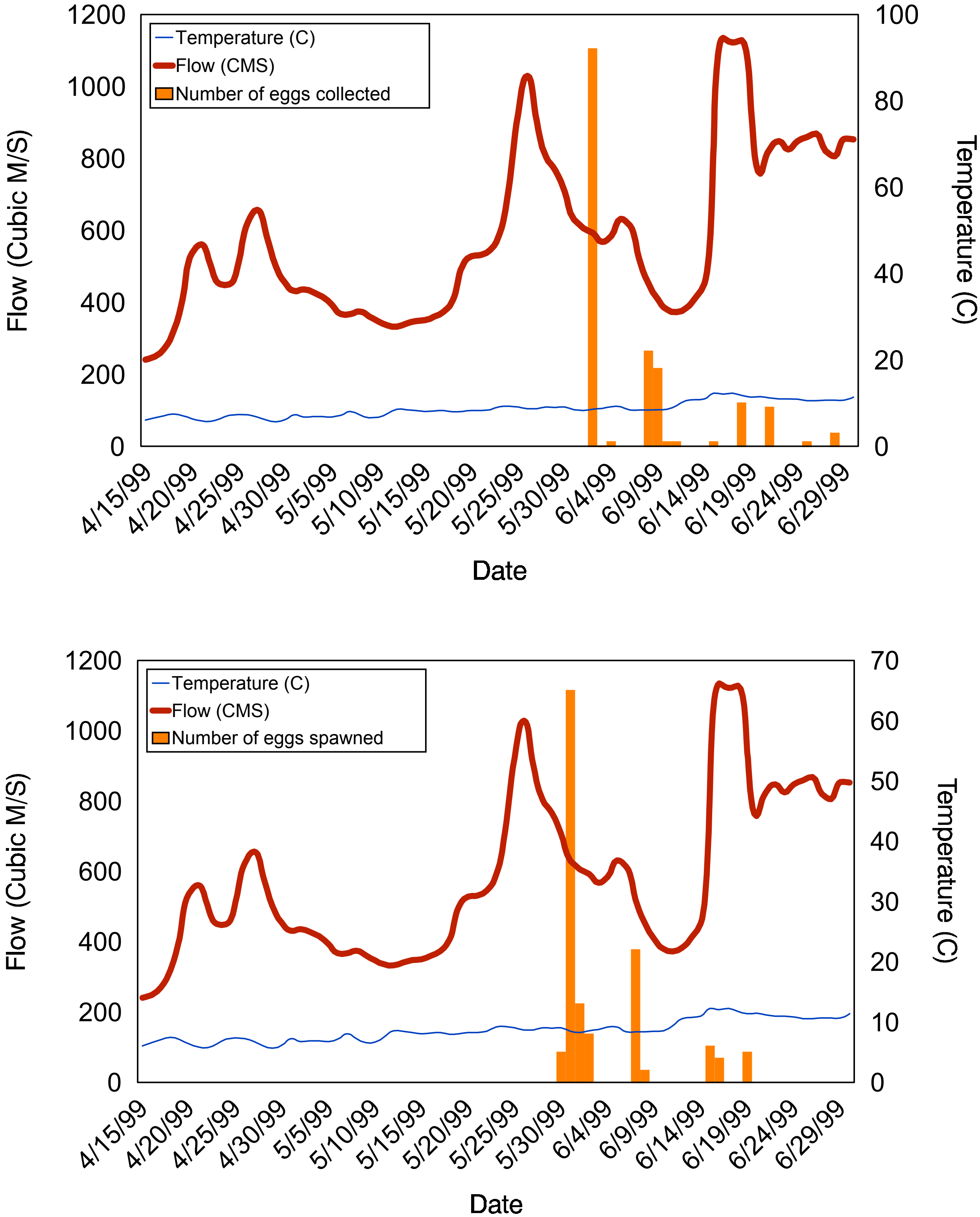

Figure 3. Top figure is collection date, number of eggs, temperature (°C), and flow (m^3/s), Kootenai River at Bonners Ferry, Idaho, 1999. Bottom figure is spawn date, number of eggs, temperature (°C), and flow (m^3/s).

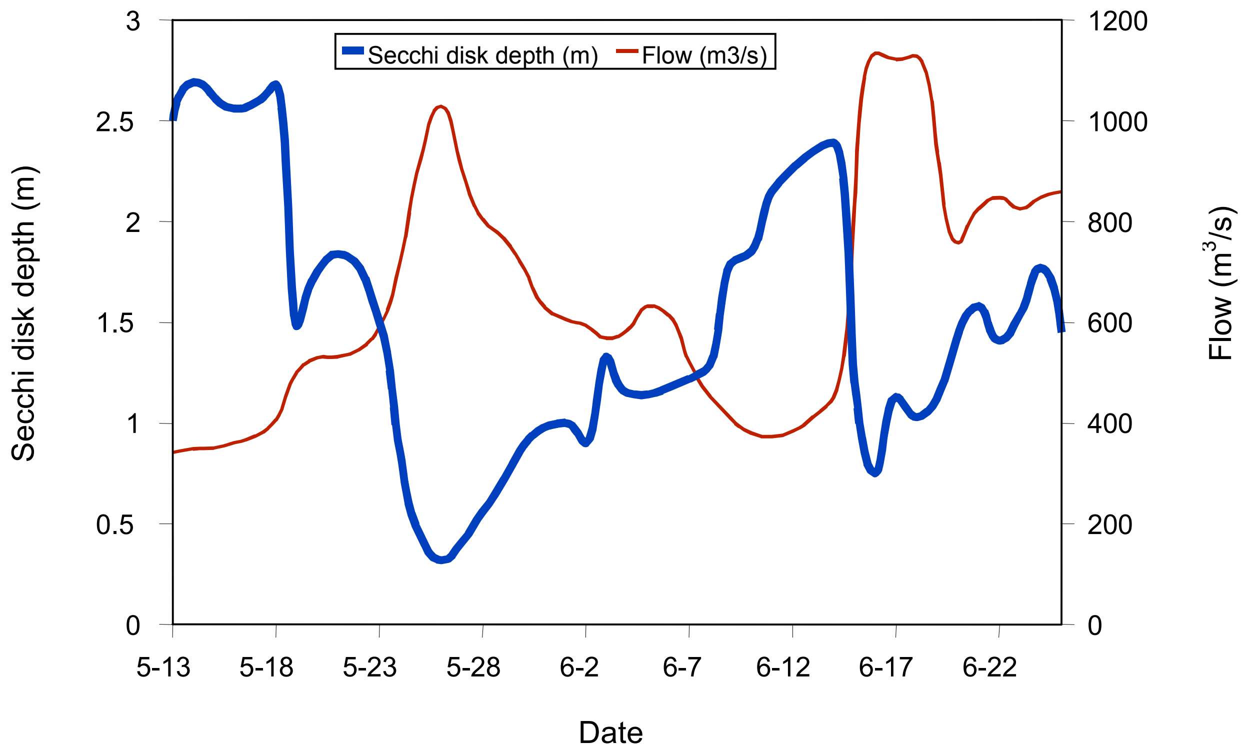

Figure 4. Secchi disk depth (m) and flow (m^3/s) in the Kootenai River from May 13 to June 25, 1999.

Adult White Sturgeon Sampling

Forty-six adult white sturgeon were captured with 4,091 hours of angling and set-lining effort between March 1 and March 25, 1999 (Table 1). Three more adult sturgeon were incidentally captured in juvenile gillnets during July and August 1999. Twenty-nine of the 49 sturgeon captured (62%) were recaptures from previous years. None were recaptures of fish originally caught in 1999.

Catch per unit effort (CPUE) for adult white sturgeon caught by angling and setline gear was 0.10 and 0.01 fish/rod or setline h, respectively. Catch per unit effort for adults captured in gillnets during juvenile sampling was 0.01 fish/gillnet h (Table 1).

A total of 45 biopsies were performed by the Idaho Department of Fish and Game (IDFG) on adult sturgeon during 1999 to determine sexual maturity stage of ovaries and testes (17 females, 22 males, 6 unknown) (Appendix 1). Sonic and radio tags were attached to six female and two male reproductively mature sturgeon during this effort.

Adult White Sturgeon Telemetry

Migration of Monitored Sturgeon in 1999

We monitored the movements of 62 adult sturgeon from September 1, 1998 to August 31, 1999 (Figure 5, Table 2, and Appendices 2a, 2b, 2c, 3a, and 3b). These included fish in Kootenay Lake, BC and the Kootenai River in Idaho and BC. The total included 37 females and 25 males. A total of 38 of the 62 adult sturgeon were monitored in the Kootenai River (Table 2). Of this total, 11 (five females and six males) moved to the spawning reach from various staging or overwintering areas (Table 2 and Appendices 2a, 2b, 2c, 3a, and 3b). One additional female (sonic code 36) moved into the reach from an overwintering location just downriver (Flemming Creek/lower Shorty's Island). Eleven fish were located in the spawning reach (rkm 228–246) during times when eggs were collected (Table 3), but 12 are thought to have spawned (Table 2). Two males (174 and 2202) most likely had previously shed their tags. Three females (348, 882, and 2189) remained a few km downstream of the spawning reach and may not have spawned, but biopsies indicated they were mature. In April, several mature fish, three males (110, 785, and 624), and one female (619), moved into the Shorty's Island reach but left before spawning occurred (Appendices 2a, 2b, 2c, 3a, and 3b).

Boat Telemetry

Boat telemetry for sturgeon locations was carried out from September 1998 through August 1999 (Figure 5). A total of 141 trips were made for a total of 372.7 h during which 524 white sturgeon locations were made. The most active months for white sturgeon telemetry took place from April through June with about 50 h each month (Figure 5).

Fixed-receiver Telemetry

Fixed site 1 logged data April 7 through June 23. Site 2 operated April 13 through June 23. Site 3 collected data April 2 through June 2. These dates corresponded to the period of upriver movements of spawning fish as noted by boat, aerial, and fixed-station telemetry. Fixed-location receiver 3 provided the most valuable information, because it was located at Bonners Ferry; only that information is presented. Only locations verified by boat or aerial telemetry are discussed in our analysis.

The 3-element Yagi antennas detected the movements of 10 fish past one or more of the three fixed stations. This included five females (890, 886, 619, 221, and 36) and five males (878, 787, 785, 624, and 394). These upriver movements were all supported by previous and later locations of the same frequencies by boat and aerial tracking. Two males, 785 and 624, were detected as high as the upriver station (site 3) at Ambush Rock (244.5). Male 785 was detected at site 3 from April 12 through April 16, which represents its furthest known upriver location. Male 624, last located in Kootenay Lake, was recorded at site 3 several times on April 12 and 13. He was last detected by boat telemetry on May 28 at rkm 244.0.

Table 1. Sampling effort and number of adult and juvenile white sturgeon caught by the Idaho Department of Fish and Game in the Kootenai River, Idaho, March 1, 1999 to August 31, 1999.

Gear type	**Hours of effort**	**Number of juvenile sturgeon caught (No. individuals)**	**Number of adult sturgeon caught (No. of recaptures from previous years)**	**Juvenile CPUE (fish/h)**	**Adult CPUE (fish/h)**
Hoopnet	34,608	19 (19)	0	---	---
Gillnet (2.4-7.6 cm mesh)	342.8	135 (132)	3	.39	.01
Angling[a]	113	0	11	---	.10
Setline[a]	3,978.4	2 (2)	35	.0005	.01
TOTAL	**39,042**	**156 (153)**	**49 (29)**		

[a] Gear targeting adult white sturgeon only.

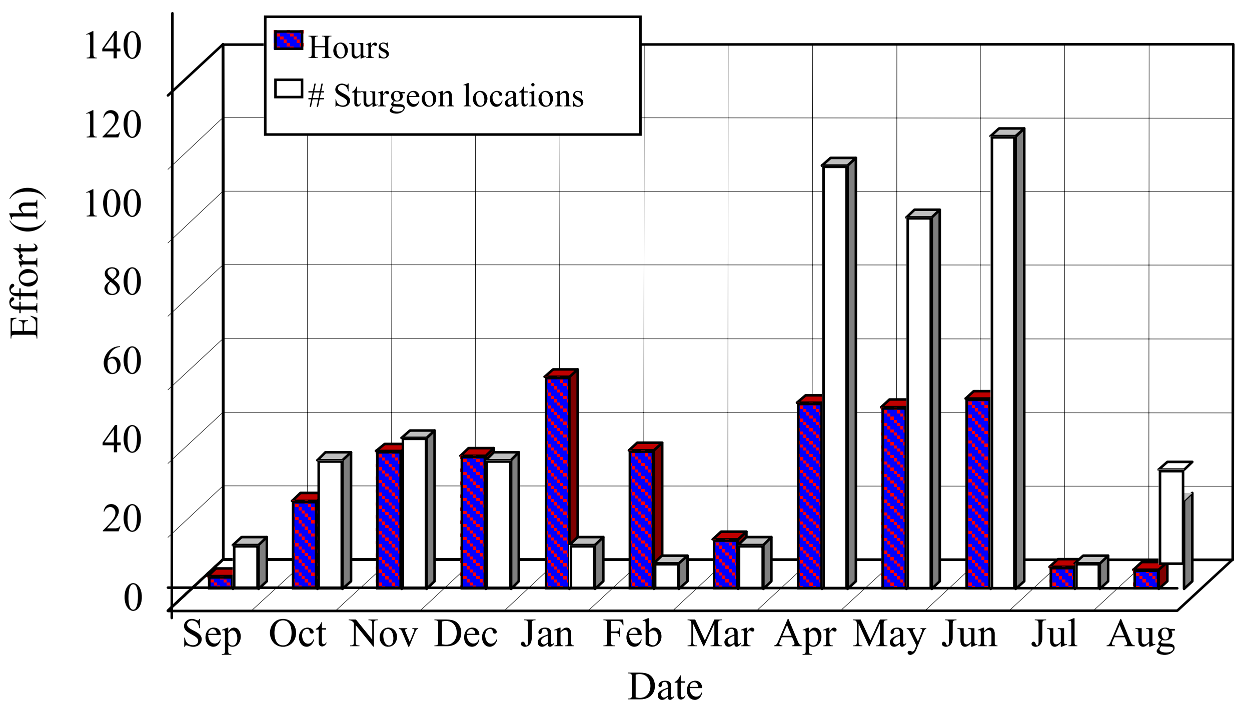

Figure 5. Telemetry effort (hours) and number of times white sturgeon were located from September 1, 1998 to August 31, 1999, Kootenai River, Idaho. Telemetry effort and white sturgeon locations share the same axis.

Table 2. Upriver locations of white sturgeon monitored in the Kootenai River from April 1, 1999 through August 31, 1999 (some fish moved out of Kootenay Lake, British Columbia).

Fish #		Tagging location (rkm)	Date tagged	Highest rkm (date)		Last date located above rkm 225
Male	**Female**			**>122<225**	**>225**	
—	36[a]	214.9	3/11/98	—	238.0(6/3)[b]	Shed tag 6/24
110	—	215.5	3/17/99	—	230.3(4/13)	[c]
124[d,e]	—	78.0	8/1/96	—	—	—
174	—	215.4	3/9/98	—	231.0(4/12-6/24)[b]	Shed ~ 8/98?[c]
—	221[a]	205.0	3/1/99	—	239.8(6/3)	6/16
—	348[a]	203.0	4/1/94	[b]	227.5(8/12)	6/17[f]
394[a]	—	215.6	3/11/99	—	235.5(6/11)	6/17
407	—	215.6	3/6/96	—	231.0(4/12-8/19)[b]	[c]
—	526[a]	205.0	3/1/99	—	235.2(6/1)	6/1
—	617	215.6	3/17/97	130.0(7/27)	—	—
—	619[a]	215.0	3/20/95	—	244.5(4/13)	5/12
620[e]	—	205.0	3/20/95	—	—	—
624[a]	—	215.4	3/24/95	—	244.5(4/12,13)	5/28
—	625[e]	215.4	3/24/95	—	—	—
—	628[e]	215.0	3/29/95	—	—	—
635[e]	—	215.4	3/6/98	—	—	—
—	636	205.0	4/4/95	132.5(7/27)	—	—
—	716[e]	215.8	3/5/96	—	—	—
—	718[e]	215.6	3/5/96	—	—	—
720	—	215.6	3/6/96	—	—	—
732[e]	—	215.6	3/14/96	—	—	—
773	—	215.6	3/18/99	213.3[g]	—	—
779[e]	—	215.7	3/4/97	—	—	—
781[e]	—	215.5	3/10/97	—	—	—
785[a]	—	215.7	3/13/97	—	244.5(4/12-16)	4/16
787[a]	—	215.6	3/18/97	—	237.5(5/3-24)	6/17[f]
—	788	215.6	3/18/97	136.0(8/24)	—	—
811[e]	—	215.5	3/2/98	—	—	—
—	814	205.0	3/2/98	215.5(Apr-Aug)[b]	—	—
—	818[e]	215.5	3/16/98	—	—	—
819[e]	—	215.1	3/17/98	—	—	—
878[a]	—	205.1	3/3/99	—	231.0(6/18)	6/21
—	882	215.6	3/17/99	215.5(Apr-Jun)	—	—
—	886[a]	205.2	3/16/99	—	230.3(5/24-31)	5/31
—	890[a]	215.6	3/24/99	—	230.9(6/7)	6/18
2057[e]	—	215.0	3/29/95	—	—	—
—	2189	215.7	3/17/99	—	225.0(8/19)	—
2202	—	215.1	3/17/98	—	234.0(6/1-8/31)[b]	Shed ~5/98?[c]
n = 20	n = 18	Combined (n = 38)				
n = 5	n = 7	Spawners (n = 12)				
n = 15	n = 11	Non-spawners (n = 26)				

[a] These fish were suspected spawners in 1999.
[b] These fish over-wintered in this section.
[c] These fish never dropped below river kilometer 225.
[d] These fish were not sexed prior to tagging.
[e] These fish made no upriver movements out of Kootenay Lake in 1999.
[f] These fish had only one location below river kilometer 225.
[g] This fish had only one location from 4/1/99 through 8/31/99.

Fixed-wing Telemetry

Fixed-wing flights took place from April 1 through August 12, 1999. All flights occurred in conjunction with tracking flights for tagged bull trout *Salvelinus confluentus* and rainbow trout *Oncorhynchus mykiss* (Walters, In Progress). Eleven flights were made searching for white sturgeon from Bonners Ferry to Kootenay Lake. In approximately 15 hours of flying, 104 sturgeon locations were made. This accounted for 63.4% of the fish tags searched for. Sixteen different potential spawners were located. These included 10 females (36, 163, 221, 348, 526, 628, 882, 886, 890, and 2189) and six males (110, 394, 720, 785, 787, and 878). Locations were recorded to the nearest 0.1 rkm. The majority of the flying occurred from Bonners Ferry (rkm 245.0) to the Canadian border (rkm 170.0), but also included three trips to the Kootenai River Delta (rkm 122.0 to 113.0). Eight fish were located in the river only; two fish were found only in the lake, and six fish were located in both the river and the lake.

Artificial Substrate Mat Sampling

We sampled for 3,387 mat days (a mat day is one 24 h set) in the Kootenai River during white sturgeon spawning in 1999 (Table 4). Sampling with mats began May 3 and ended June 28, 1999. Although mats were checked daily, high water conditions and debris in the river made it difficult to find all of the mats each day. Thus, some mats were set for several days before they could be relocated. The total sampling time for egg mats was 81,282 h. A total of 184 sturgeon eggs were collected (Figure 3).

Sampling mats collected eggs within three of 10 different geographic river sections (Table 4 and Appendix 4). The Middle Shorty's Island reach (rkm 229.6-231.5) produced the most eggs (144) with 388 mat days of effort; the Refuge section (rkm 234.8-237.5) with 616 mat days of effort produced 21 eggs, and the Lower Shorty's section produced 19 eggs with 548 days of mat effort. No eggs were collected above the Refuge section (>rkm 240.5) with 996 mat days of effort.

Table 3. Fish tracked to sections of the Kootenai River, Idaho where white sturgeon eggs were spawned (back-calculated to spawning date) within 24 hours preceding spawning date.

Location	Egg spawn date[a]	Fish Number: Males	Fish Number: Females[b]
Lower Shorty's Island (rkm 227-231.5)	May 30, May 31, June 1, June 2, June 7, June 8, June 15, June 16	174, 394, 407, 787, 878	36, 221, 890, 886
Middle Shorty's Island (rkm 229.6-231.5)	June 1 June 7	110, 787	None
Wildlife Refuge (rkm 234.8-237.5)	May 31, June 1, June 16, June 19	None	36, 526[c]

[a] This assumes that eggs were spawned in the same river reach where they were collected.
[b] Fish 619 was not detected.
[c] Fish 526 was not detected by the fixed receivers.

Table 4. Location (rkm), depth (m), effort, and white sturgeon egg catch by standard artificial substrate mats, Kootenai River, Idaho, 1999.

Geographical description	River location (rkm)	Depth range (m)	Total sample hours[a] (days)	Number white sturgeon eggs
Lower Shorty's Island	228.0-229.5	5.1-21.3	13,155.5 (548)	19
Middle Shorty's Island	229.6-231.5	2.7-18.6	9,315.8 (388)	144
Upper Shorty's Island	231.6-233.4	1.2-13.7	8,923.9 (372)	0
Myrtle Creek	233.5-234.7	3.7-16.8	11,197.2 (467)	0
Refuge	234.8-237.5	3.1-19.5	14,785.3 (616)	21
Deep Creek	237.6-240.5	4.6-18.6	9,319.9 (388)	0
Hatchery	240.6-243.9	2.1-12.2	7,413.8 (309)	0
Ambush Rock	244.0-244.6	NA	0	0
US 95	244.7-246.6	0.9-22.3	4,159.8 (173)	0
Upper Pump Station	246.7-247.7	0.6-11.3	3,010.3 (125)	0
All Sections	228.0-247.7	0.6-22.3	81,281.5 (3,387)	184

[a] One mat sample is equal to the time a mat is in the river before it is pulled and checked.

Depth of artificial substrate mat placement ranged from 0.6 m to 22.3 m (2.0 ft to 73.0 ft) for all mats (Table 4). On several occasions, weather and river conditions made it hazardous to collect all habitat parameters at egg collection sites. Mats that collected eggs ranged from 7.6 m to 17.1 m (25 ft to 56 ft) in depth, averaging 11.4 m (38 ft) (Appendices 4 and 5). Surface velocities (0.2 depth) at 15 egg collection sites ranged from 0.41 m/s to 1.12 m/s (1.34 ft/s to 3.67 ft/s) and averaged 0.77 m/s (2.53 f/s) (Appendices 4 and 5). Velocities near the river substrate (0.8 depth) at 15 of the egg collection sites ranged from 0.33 m/s to 0.96 m/s (1.08 ft/s to 3.15 ft/s) and averaged 0.68 m/s (2.23 ft/s). Mid-column velocity ranged from 0.45 m/s to 0.95 m/s (1.48-3.12 ft/s) and averaged 0.73 m/s (2.38 ft/s) (Appendices 4 and 5).

One hundred thirty-one (71%) of the 184 white sturgeon eggs collected in 1999 were viable. Development ranged from stage 12 to 27 (1 h to 11 days old), with 57% of the viable eggs at stage 21 (about 2.4 days) or younger (Appendix 5). The oldest egg was estimated at 256 hours old, or about 10.7 days.

Based on ages of viable eggs and the dates of egg collection, we estimated that white sturgeon spawned during at least nine days in 1999 (Figure 3). The first spawning episodes were estimated to have occurred from May 30 through June 2. The next episodes were estimated to have occurred June 7 and 8, then on June 15, 16, and 19.

Experimental Drift Nets

Drift nets were only fished for three days, because high flows and drifting logs moved them downriver. As a result, they could not be found or retrieved until flows subsided. Within these two days of sampling, nets collected three eggshells and one unidentified larval fish.

Larval Sturgeon Sampling

No larval sturgeon were captured during 1999. Between June 4 and July 6, we sampled 138,917 m^3 of water in 62.96 h with dual half-meter (120,319 m^3) and D-ring nets (18,598 m^3) between rkm 120.0 and 230.9 in the Kootenai River. Sampling with the dual half-meter nets was divided about equally between surface and subsurface tows. Sampling was primarily done at night. Duration of tows ranged from 7 to 32 minutes. Although no larval sturgeon were collected in larval nets, 11 larval suckers *Catostomus sp.* were collected.

Juvenile White Sturgeon Sampling

We expended 343 hours of gillnet sampling effort to capture 135 (132 individual) juvenile white sturgeon (Table 1). An additional two wild juvenile sturgeon were incidentally captured on adult setline gear (Table 1 and Appendix 7). Nineteen juvenile sturgeon were captured with 34,608 h of hoopnet effort during a companion study (Paragamian and Whitman, In Progress). No juvenile sturgeon was captured with 5 h of benthic trawl effort. Catch per unit effort for juvenile sturgeon captured by gillnet was 0.39 fish/h. Of the 132 individual juvenile sturgeon captured, two were wild, and 130 were hatchery progeny (Appendix 6 and 7). In addition, two unmarked wild juveniles were captured by British Columbia Ministry of Environment Lands and Parks (BCMOELP) fisheries staff during gillnet sampling in the Lower Kootenai River and in Kootenay Lake (rkm 122.0-160) (Spence and Andrusak, In Progress).

Juvenile White Sturgeon Food Habits

We examined the stomach contents of 24 age-4 hatchery white sturgeon captured in the Kootenai River (Table 5). These fish were released in May 1997 and were collected for food habit analysis during July and August 1999.

A grand total of 7,593 identifiable food items of 15 different invertebrate families or taxa were found in the 24 sturgeon stomachs (Table 5). An unidentifiable fish was found in each of three stomachs. Chironomid larvae and pupae comprised the greatest proportion of the diet, contributing 6,262 items (82%); oligochaetes were second at 625 items (8%). Unknown invertebrate parts comprised 84% of the dry weight while chironomids contributed 9% (Table 5).

Age and Growth of White Sturgeon

Adults

Ages of all wild white sturgeon captured in 1999 ranged from 4 years to 52 years (Figure 6). These fish are from year classes between 1947 and 1995.

Growth for recaptured sturgeon averaged 1.34 cm (SD = 2.89) (0.53 in, SD = 1.14) fork length (FL) and 1.88 cm (SD = 4.00 cm) (0.74 in, SD = 1.57) total length (TL) per year. Intervals between recaptures and measurement of growth ranged from two to six years. The maximum annual growth of an adult (age-25) was 29.80 cm (11.73 in) FL and 31.91 cm (12.56 in) TL. We note there may have been variation in the precision of length measurements between individuals and agency, which will affect our accuracy.

Table 5. Food items in 24 age-4 hatchery white sturgeon captured in the Kootenai River, Idaho, 1999.

Food Item	Total number of items	Percent of total contents	Percent of stomachs containing item	Total dry weight (g)
Diptera				
Chironomidae larvae	6,062	80	100	1.944
Chironomidae pupae	200	2	80	0.486
Ephydridae	1	<.1	4	0.0001
Athericidae	1	<.1	4	0.0059
Simulidae	11	.1	28	0.0013
Tabanidae	5	<.1	12	0.0249
Ceratopogonidae	382	5	100	0.0252
Deltocephalinae				
Cicadellidae	1	<.1	4	0.0001
Ephemeroptera				
Heptageniidae	6	<1	16	0.0065
Baetidae	191	2	72	0.3647
Ephemerellidae	1	<.1	4	0.0011
Baetidae subadult	1	<.1	4	0.0021
Tricoptera				
Hydropsychidae	77	1	76	0.1628
Plecoptera				
Perlodidae	3	<.1	8	0.0519
Pteronarcyidae	15	2	20	0.2124
Hemiptera				
Corixidae	8	.1	20	0.0115
Oligochaeta	625	8	80	0.1045
Other				
Unknown invertebrate parts	--	--	100	18.227
Osteichthyes	3	<.1	12	0.0441

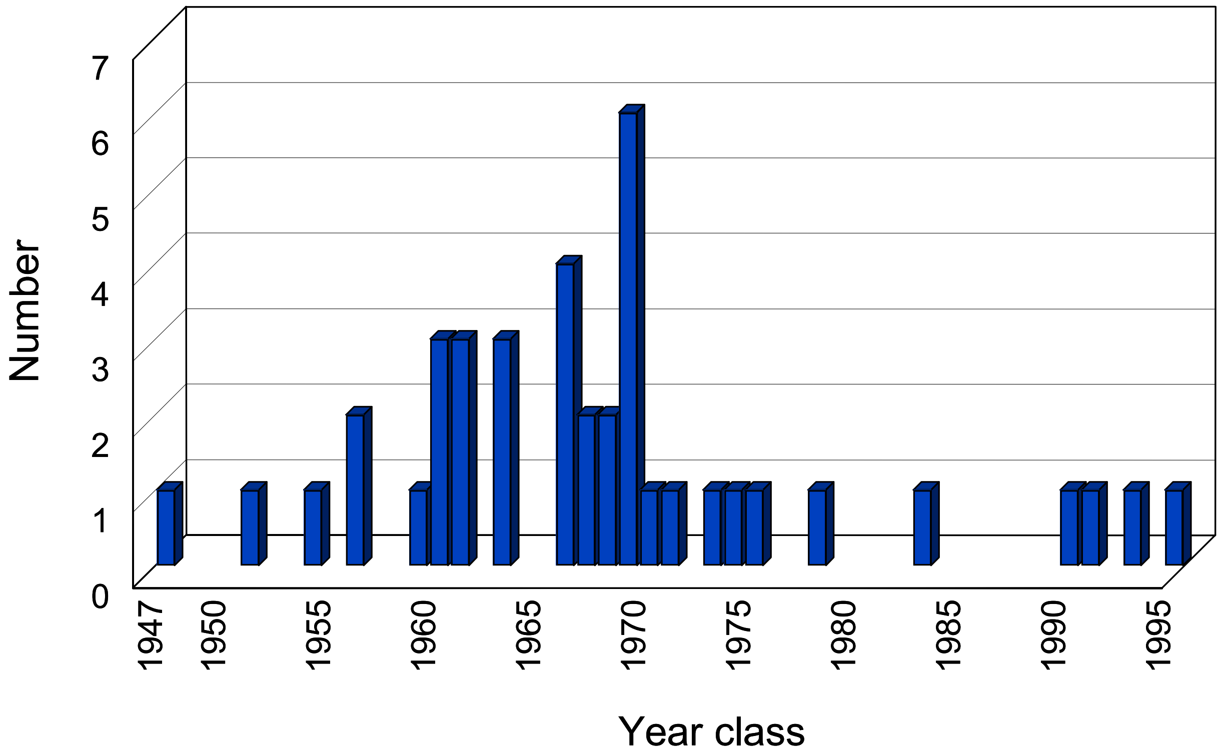

Figure 6. Number and year class of Kootenai River white sturgeon captured and aged during 1999.

We calculated relative weight (Beamesderfer 1993) for FL for adult white sturgeon captured during the 1999 sampling period. Fork length W_r for adult white sturgeon ranged from 37 to 111, and the mean was 87 (SD = 15).

Juveniles

Lengths of four wild juvenile white sturgeon captured between August 1, 1998 and August 31, 1999 were 26.0 (age-4), 37.0 (age-6), 56.0 (age-8), and 69.0 cm FL (age-9) (10.2, 14.6, 22.0, and 27.1 in, respectively); or 28.5, 41.0, 64.5, and 81.0 cm TL (11.2, 16.1, 25.4, and 31.9 in TL), respectively. Calculated annual growth for 631 recaptured (combined for 1990, 1991, 1992, and 1995 year classes) hatchery-reared and released juvenile sturgeon was 12.21 $\pm$7.75 cm (4.89 $\pm$ 3.10 in) FL and 13.92 $\pm$ 8.71 cm (5.57 $\pm$ 3.48 in) TL. Maximum measurable growth was 35.23 cm (14.09 in) FL and 44.10 cm (17.64 in) TL. Calculated growth for three wild juvenile sturgeon was 4.20 $\pm$ 3.64 cm (1.68 $\pm$ 1.46 in) FL and 4.78 $\pm$ 4.24 cm (1.91 $\pm$ 1.70 in) TL. Maximum measurable growth for wild juvenile sturgeon was 8.49 cm (3.40 in) FL and 9.25 cm (3.70 in) TL.

We calculated FL W_r for 130 juvenile hatchery white sturgeon of the 1995 brood year captured during the 1999 sampling period. Hatchery juvenile white sturgeon FL W_r ranged from 38 to 142, and the mean was 87 (SD = 16), FL W_r for the six juvenile wild white sturgeon ranged from 92 to 109 with a mean of 92 (SD = 17).

Contaminants Analysis

Results of ovarian tissue contaminant analysis indicate detectable presence of seven metals, four organochlorine pesticides, and one PCB (Tables 6 and 7). Concentrations of copper and zinc were significantly higher ($p = 0.02$ and $p = 0.005$), and lead was significantly lower ($p = 0.018$) in ovarian tissue samples collected between 1997 and 1999 than in samples collected from 1989 through 1991 (Apperson and Wakkinen 1992).

Copper and the PCB arochlor 1260 concentrations in embryos also significantly correlated with percent mortality of developing embryos ($p < 0.05$, $r = 0.568$, and 0.800, respectively). Additional analyses of the egg rearing studies are underway.

Table 6. Number of samples and concentrations of metals detected in Kootenai River white sturgeon ovarian tissue, collected 1997-1999 (n = 33).

Contaminant	Number of Samples (% of total)	Concentration range (ppm)	Mean ± Standard Deviation
Arsenic	17 (52)	0.087 – 1.20	0.314 ± 0.289
Cadmium	19 (58)	0.001 – 0.940	0.064 ± 0.214
Copper	30 (91)	0.58 – 6.90	2.394 ± 1.562
Iron	33 (100)	15.0 – 56.0	27.97 ± 9.936
Lead	18 (55)	0.045 - 0.880	.175 ± 0.195
Selenium	33 (100)	0.55 – 12.0	1.762 ± 2.016
Zinc	33 (100)	19.0 – 170.0	37.0 ± 29.090

Table 7. Number of samples and concentrations of organochlorine pesticides and Polychlorinated Biphenyls (PCBs) detected in Kootenai River white sturgeon ovarian tissue, collected 1997-1999 (n = 34).

Contaminant	Number of Samples (% of total)	Concentration range (ppb)	Mean ± Standard Deviation
DDE	34 (100)	48.0 – 1800.0	296.118 ± 372.281
DDT	12 (35)	22.0 – 88.0	44.25 ± 18.415
Arochlor 1260	25 (74)	160.0 – 1300.0	460.0 ± 288.401
Dieldrin	1 (3)	49.0	---
Aldrin	5 (15)	53.0 – 98.0	77.0 ± 16.837

Contaminant analysis of water and substrate samples at eight sites within the sturgeon spawning and staging area indicate zinc and iron concentrations in some of the water samples exceed Environmental Protection Agency (EPA) and Idaho water quality criteria. The PCB Arochlor 1260 was also detected in the Flemming Creek (rkm 225) sample at a level that exceeded EPA and Idaho water quality criteria. Arrangements are being made for more intensive sampling at these sites. Results from soil samples indicate that substrate concentrations of metals, organochlorine, and PCB compounds are at or below non-polluted and background levels for similar systems.

Liver lesion analysis in hatchery-reared (brood year 1995) and released (1997) juvenile sturgeon showed signs of alterations. Laboratory results are still pending for analysis of juvenile tissue, acetylcholinesterase, and DNA adjunct analysis.

Egg Incubation and Temperature Experiment

Approximately 15,000 white sturgeon eggs were extracted for determination of stage at incubation time. At the preparation of this report, eggs were in the process of being staged by USGS personnel, but no information was available. This information will be published upon completion of staging and analysis.

DISCUSSION

The goal of this investigation is to determine environmental requirements for adequate spawning and recruitment of white sturgeon cohorts and to achieve recovery of the population. Five years of study have resulted in a substantial number of eggs collected and the capture of a few wild sturgeon recruited from several flow test years. However, we are concerned because the number of wild recruits is too low to provide management recommendations. The lack of management recommendations is due to an inadequate comprehension of how post-Libby Dam changes to the basin affect the ecosystem and an inability to consistently provide suitable conditions for white sturgeon spawning and rearing.

We do not believe a satisfactory level of white sturgeon spawning was achieved in 1999. Snowpack at the beginning of spring was about 130% of normal, but the runoff was gradual because of a cool spring. The Kootenai River rose only gradually during the spring from local run off. By May 26 it reached 1,031 m^3/s (36,370 cfs), but it began subsiding within several days. Water temperature concurrently rose to about 8°C (46.4°F), was relatively steady, and mature white sturgeon migrated to the spawning reach. Spawning began about May 30 and continued through June 8. Flow gradually receded to about 373 m^3/s (13,200 cfs) by June 11, prior to flow mitigation from Libby Dam, and spawning ceased. Spawning flows were initiated on June 13, stimulating resumption in spawning, but the main spawning events are thought to have occurred before spawning flows. About 87% of the eggs collected and 66% of the spawning events occurred before the augmented spawning flows. Although a few more spawning events were recorded after spawning flows, some females are thought to have completed spawning or abandoned the spawning reach without spawning before they occurred. The delay in spawning flows is linked to the Recovery Objective of providing warmer water for white sturgeon spawning, 10°C+ (50°F), by storing water in Lake Koocanusa and allowing it to warm. In theory, some members of the recovery team believed the warmer water would induce more spawning events.

As a result of the timing of mitigated flows for spawning in 1999, spawning reach abandonment may have occurred prior to spawning for some female sturgeon with transmitters. This is a predictable behavior trait of Kootenai River white sturgeon (Paragamian and Kruse, unpublished). Most spawning of white sturgeon in 1999 is thought to have occurred during decreasing flows from local runoff. However, after local runoff subsided, spawning ceased before spawning flows were released. Although some spawning resumed soon after mitigated flows were released, we believe some females abandoned the reach without spawning. Tagged sturgeon abandoned the spawning reach in 1992 and 1993 when mitigated flows did not augment the drop in flow of local runoff. No eggs were collected in 1992 and only two in 1993. A similar situation was apparent during the 1998 spawning season, when white sturgeon spawning ceased after local inflow subsided but resumed after mitigated flows; unlike other years, white sturgeon with transmitters did not leave the spawning reach in 1998.

Spawning of Kootenai River white sturgeon in a reach of river comprised of sand was unexpected and is a major concern for egg and larval survival (Paragamian et al. 1996; Paragamian et al. 1997; Paragamian et al. 1998). Eggs spawned over this substrate are often coated in sand and may be buried within large mobile sand dunes (Paragamian et al. 1998). White sturgeon eggs are relatively large (2 to 3 mm) and adhesive. In the Kootenai River, they are unable to attach to large clean substrates found in other spawning rivers for this species (Brannon 1984). This spawning habitat characteristic and the unknown survival of eggs and larvae is a major concern because, after five years of flow mitigation, the number of juvenile recruits captured remains much lower than anticipated. However, survival of hatchery sturgeon released at age-2+ appears good (Paragamian et al. 1998), suggesting a “bottleneck” occurs between the egg and age-2+ stages.

The location of white sturgeon spawning in the Kootenai River may be the result of a change from the natural elevations of Kootenay Lake (Paragamian et al., unpublished). Each spawning season, white sturgeon in the Kootenai River form three to four groups of adult spawners. Spawning usually takes place first in the lower portion of the spawning reach (rkm 228–231), but as the season progresses spawning occurs further and further upstream (rkm 232–240) (Paragamian et al., unpublished). However, spawning seldom occurs over cobble substrate at or upstream of Bonners Ferry (rkm 245+). One possible reason for the spawning location quandary may be the lowering of Kootenay Lake elevation each spring, which began concurrent with the completion of Libby Dam (Duke et al. 1999). The Kootenai River is of low gradient and Kootenay Lake has a backwater effect on the river up to Bonners Ferry. Paragamian et al. (unpublished) examined the movement and spawning location of Kootenai River white sturgeon from 1994 through 1998 and hypothesized sturgeon were spawning in the location of suitable current velocities, but as the lake elevation rose (to store spring runoff) they moved further upstream to relocate to the preferred velocities. Some researchers believe white sturgeon key on high current velocities for spawning, and coarse substrates are the result of the sorting of particles by higher velocities (Parsley et al. 1993). Buckley and Kynard (1982) indicated water velocity and depth might be more important to spawning shortnose sturgeon *A. brevirostrum* than depth alone in determining specific spawning location and substrate.

The only plausible, additionally known explanation for the absence of wild juvenile sturgeon may be downstream drift of larval sturgeon and subsequent rearing in Kootenay Lake, BC. Kootenai River white sturgeon have a “short two-step migration pattern,” and juveniles of sturgeon populations with this life history scheme usually rear in large lakes (Bemis and Kynard 1997). It is possible a substantial portion of young sturgeon produced during flow test years could be rearing in Kootenay Lake. Sampling for white sturgeon in Kootenay Lake since 1971 has produced many unmarked sturgeon (BCMOELP file records, Nelson, BC), some of which were wild sturgeon approaching maturity. However, considerable sampling by BCMOELP fisheries personnel in the Kootenai River and Kootenay Lake in BC has provided a capture of only three juvenile sturgeon produced since 1991 (Colin Spence, BCMOELP, Fisheries Biologist, Nelson, personal communication). An experimental measure to resolve the question of egg survival may be to release a large number of hatchery-cultured larval white sturgeon from several families. The subsequent recapture success rate of fish from that cohort could expose the "egg survival bottleneck" question. A secondary benefit of such an experiment would be the testing of our sampling gear with a known quantity of larval sturgeon at large. We must also assume that the evaluation of the success of a flow test could be compromised for the year of any release of unmarked hatchery fish.

RECOMMENDATIONS

1. Spawning migration of white sturgeon commences at temperatures above 6°C (females at about 8°C) and any drop in flow or temperature could compromise spawning. Thus, flow and temperature must be maintained or allowed to increase if adults are to be held in the spawning reach. On or about 15 April (when water temperature is 7°C to 8°C (43°F to 46°F) maintain stable or increasing flow of 425 m^3/s (15,000 cfs).

2. In the literature, high flows have been shown to be necessary to stimulate white sturgeon spawning and to maximize survival of eggs and larvae. Recommended flows at Bonners Ferry for white sturgeon spawning and rearing should be 1,130 m^3/s (40,000 cfs) for 42 d, when water temperatures approach 8°C to 10°C (46°F to 50°F).

3. Release hatchery-reared white sturgeon to determine if lack of naturally-produced sturgeon in the population is related to failure of eggs to hatch or failure of hatched eggs to survive in sand substrate.

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APPENDICES

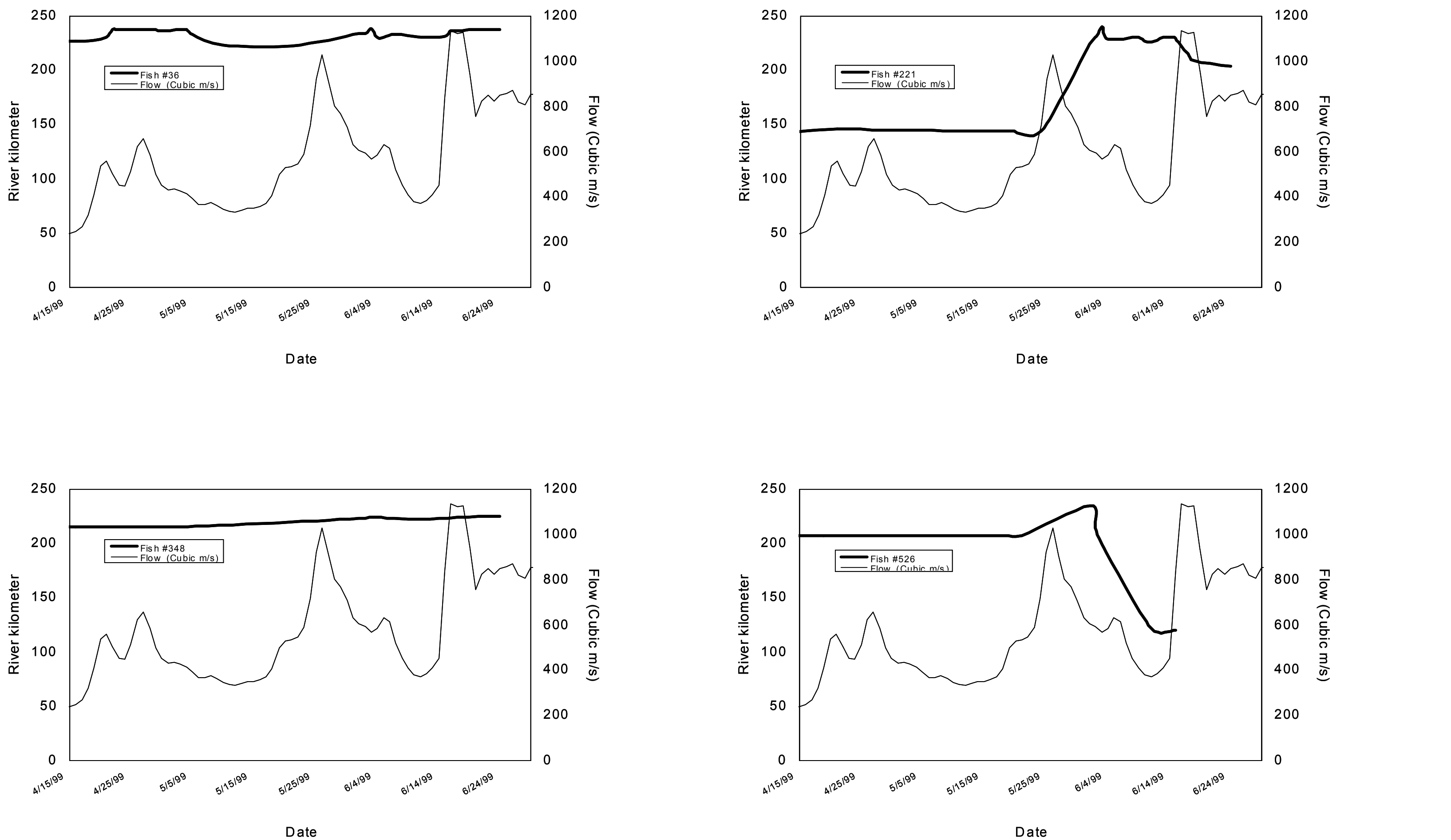
Appendix 1. Sexual development of white sturgeon sampled by Idaho Department of Fish and Game, Kootenai Tribe of Idaho, and British Columbia Ministry of Environment Lands & Parks in the Kootenai River, Idaho, 1989 through 1999.

Categories of sexual development		Percent (number) of sample by year										
Category/Sex	Description of development	1989	1990	1991	1992	1993	1994	1995[a]	1996[a]	1997	1998	1999
0/Unknown[b]	Gonad undifferentiated or not seen	32 (58)	14 (15)	6 (3)	2 (1)	0	24 (14)	0	45 (67)	19 (14)	15 (14)	13 (6)
1/Female	Previtellogenic: No visual signs of vitellogenesis; eggs present but have average diameter <0.5 mm	14 (25)	12 (13)	8 (4)	12 (5)	0	5 (3)	11 (3)	5 (7)	14 (10)	11 (10)	9 (4)
2/Female	Early vitellogenic: Eggs are cream to gray; average diameter 0.6-2.1 mm	7 (12)	7 (8)	4 (2)	2 (1)	5 (1)	2 (1)	0	4 (6)	0	9 (8)	2 (1)
3/Female	Late vitellogenic: Eggs are pigmented and attached to ovarian tissue; average diameter 2.2-2.9 mm	6 (10)	5 (5)	8 (4)	9 (4)	53 (10)	2 (1)	0	2 (3)	1 (1)	2 (2)	5 (2)
4/Female	Ripe: Eggs are fully pigmented and detached from ovarian issue; average diameter 3.0-3.4 mm	2 (3)	5 (5)	4 (2)	9 (4)	11 (2)	14 (8)	25 (7)	5 (7)	10 (7)	4 (4)	22 (10)
5/Female	Spent: Gonads are flaccid and contain some residual fully pigmented eggs	3 (5)	1 (1)	2 (1)	0	5 (1)	0	3.5 (1)	0	0	0	0
6/Female	Previtellogenic with attritic oocytes: Eggs present but have an average diameter <0.5 mm; dark pigmented tissue present that may be reabsorbed eggs	2 (3)	0	0	0	0	0	0	1 (2)	3 (2)	0	0
R/Female	Reabsorbing eggs	0	0	0	2 (1)	0	0	0	1 (1)	0	0	0
7/Male	Non-reproductive: Testes with translucent smokey pigmentation	3 (6)	27 (30)	29 (15)	26 (11)	0	19 (11)	36 (10)	13 (20)	24 (17)	19 (18)	33 (15)
8/Male	Reproductive: Testes white with folds and lobes	32 (58)	28 (31)	18 (9)	16 (7)	21 (4)	35 (20)	21 (6)	20 (31)	29 (21)	40 (38)	16 (7)
9/Male	Ripe: Milt flowing; large white lobular testes	0	3 (3)	14 (7)	21 (9)	5 (1)	0	0	2 (3)	0	0	0
S/Male	Spent: Testes flaccid; some residue of milt	0	0	8 (4)	0	0	0	3.5 (1)	2 (3)	0	0	0

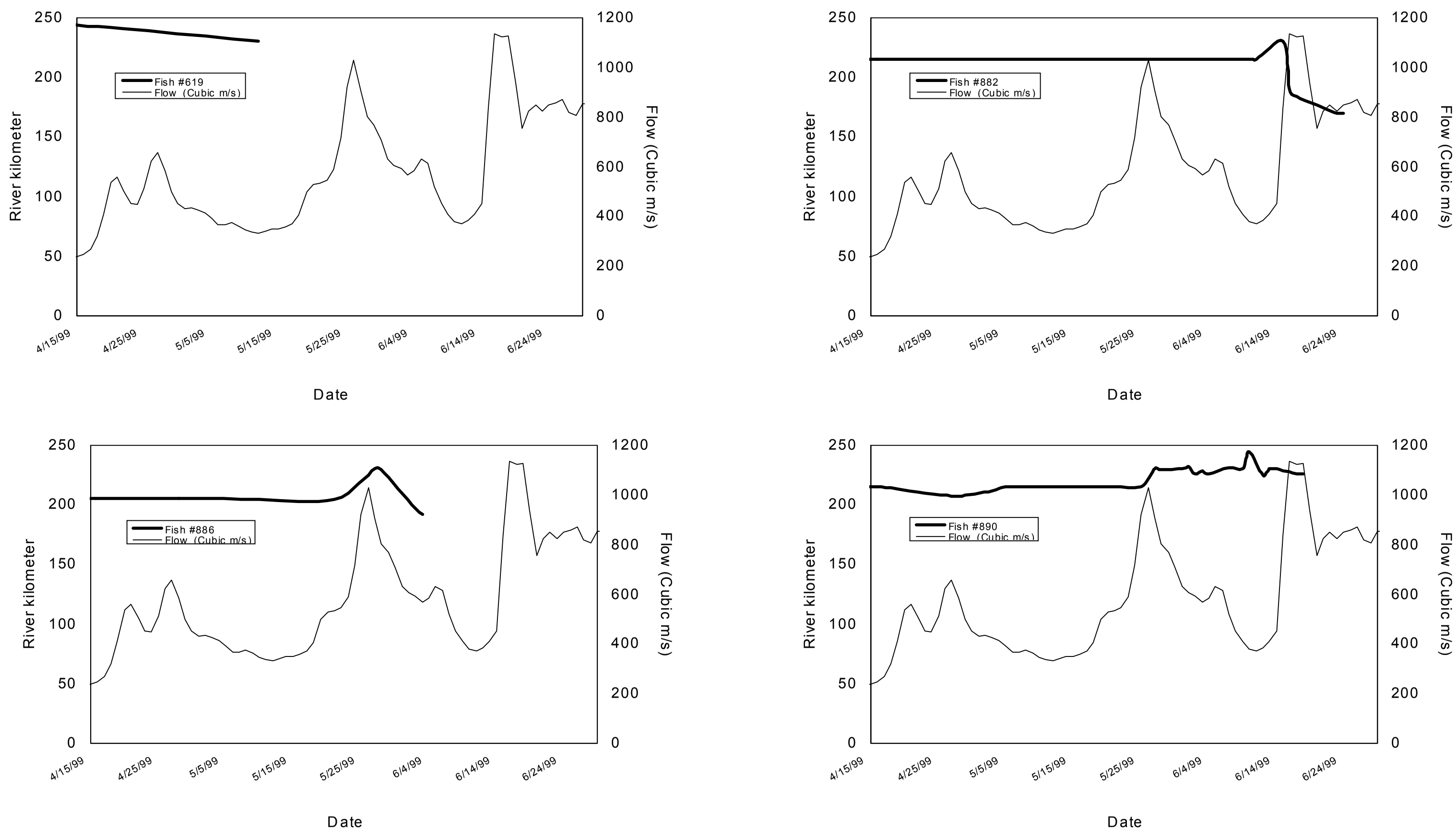
[a] Surgeries done by IDFG and KITOI were carried out on fish that externally appeared to be candidates for spawning. Surgeries done by BCMOE and those done during previous years were more randomly distributed among fish >130 cm.

[b] Fish that we did not perform surgery on were placed in the unknown category.

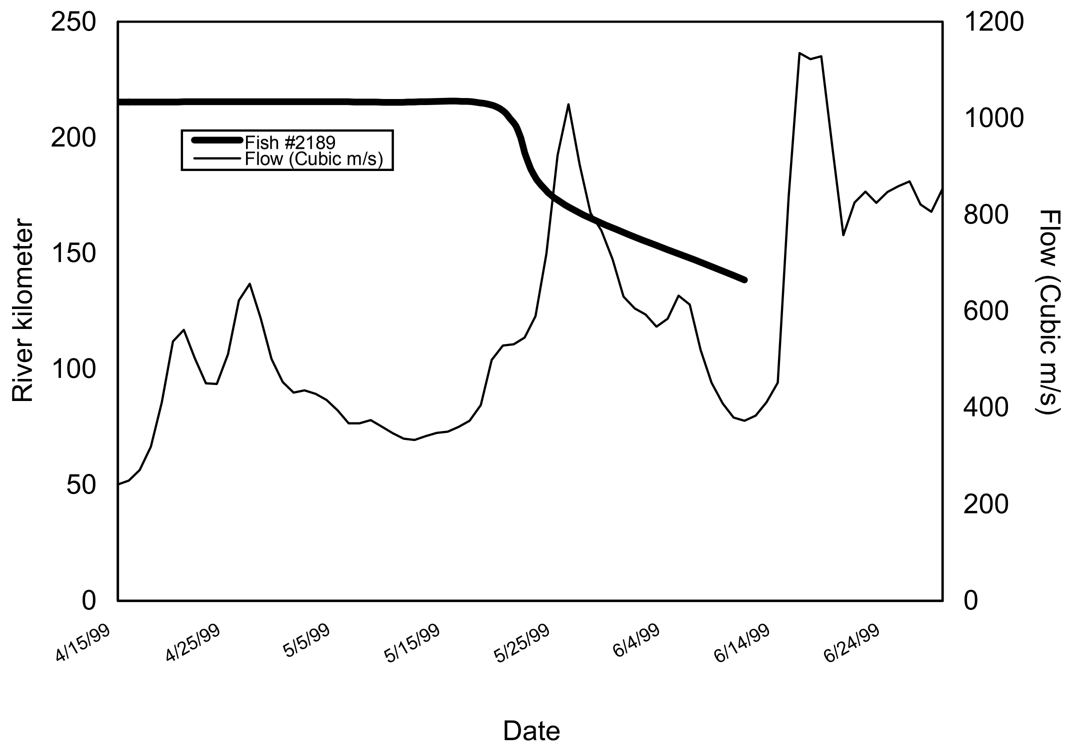
Appendix 2a. Migration and flow (m^3/s) for nine adult female white sturgeon, of which seven are believed to have spawned in the Kootenai River, Idaho in 1999.



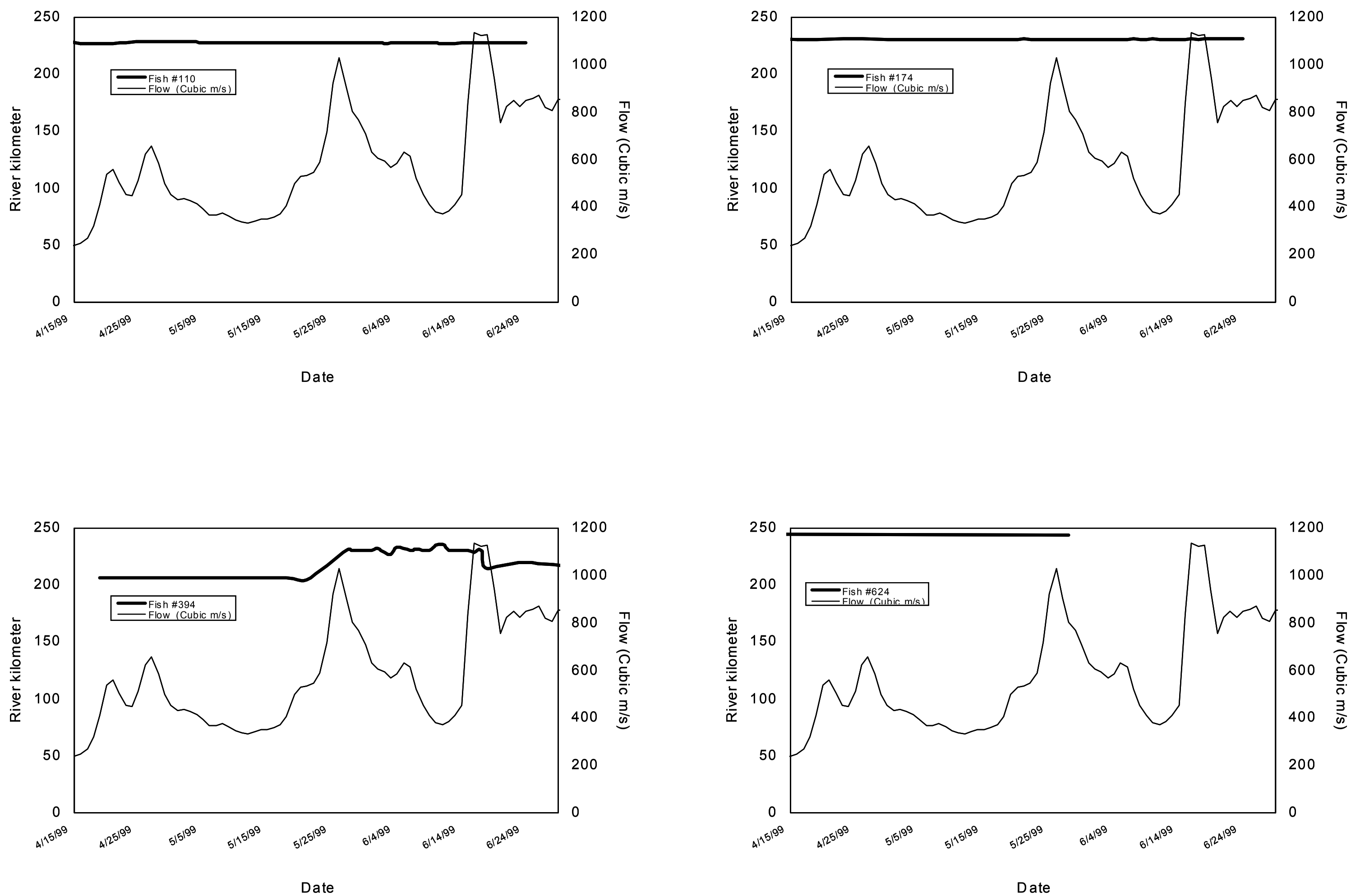
Appendix 2b. Migration and flow (m^3/s) for nine adult female white sturgeon, of which seven are believed to have spawned in the Kootenai River, Idaho in 1999.



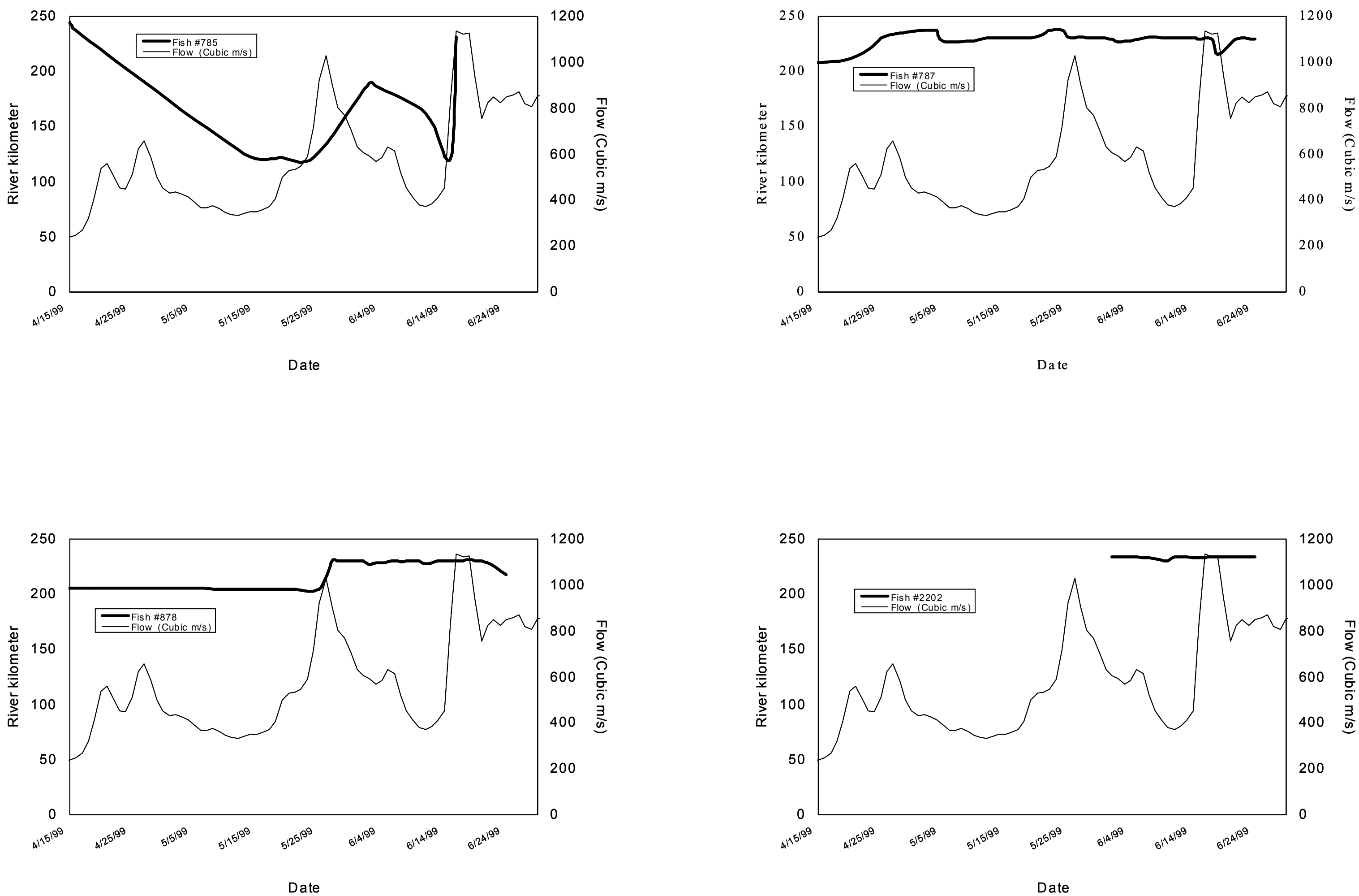
Appendix 2c. Migration and flow (m^3/s) for nine adult female white sturgeon, seven of which are believed to have spawned in the Kootenai River, Idaho, in 1999.



Appendix 3a. Migration and flow (m^3/s) for eight adult male white sturgeon, of which five are believed to have spawned in the Kootenai River, Idaho in 1999.



Appendix 3b. Migration and flow (m^3/s) for eight adult male white sturgeon, of which five are believed to have spawned in the Kootenai River, Idaho in 1999.



Appendix 4. River location (rkm), number of eggs, depth (m), temperature (°C), and velocity at sites (m/s) where white sturgeon eggs were collected, Kootenai River, Idaho, 1999.

River section (rkm)	No. Eggs	No. Mats w/eggs	Depth range (m)	Mean depth (m)	0.2[a] Velocity (m/s)	0.8[b] Velocity (m/s)	Mean velocity (m/s)
228.0-229.5	19	4	11.2 – 13.7	12.6	0.71	0.55	0.63
229.6-231.5	144	9	7.6 – 17.1	11.2	0.76	0.65	0.71
234.8-237.5	21	4	8.8 – 13.7	10.6	0.85	0.86	0.86
All locations	184	17	7.6 – 17.1	11.4	0.77	0.68	0.73

[a] 0.2 of total depth
[b] 0.8 of total depth

Appendix 5. White sturgeon egg collection locations, habitat attributes and staging data for eggs collected during the 1999 sampling season on the Kootenai River, Idaho.

Date	Rkm	Depth	No. eggs	Flow 0.2	Flow 0.8	Temp (C)	Discharge (m3/s)	Stage (number)	Spawn Date
6-2-99	231	8.8	92	--	--	8.6	593.6	Dead (23)	--
								19 (1)	6-1
								21 (63)	5-31
								22 (5)	5-30
6-3-99	231	17.1	13	.71	.69	8.8	568.4	Dead (4)	--
								18 (5)	6-2
								19 (3)	6-2
6-3-99	235.6	12	25	.72	.67	8.8	568.4	Dead (6)	--
								21 (5)	6-1
								22 (2)	5-31
6-4-99	231	15.9	1	.71	.69	9.1	585.1	Dead (1)	--
6-8-99	229.1	12.5	1	.59	.53	8.4	452.3	12 (21)	6-7
6-8-99	231	7.6	21	.41	.59	8.4	452.3	17 (1)	6-7
6-9-99	229	12.8	16	.7	.43	8.5	409.2	Dead (10)	--
								27 (6)	6-1
6-9-99	231	7.9	2	.74	.51	8.5	409.2	19 (2)	6-8
6-10-99	230.9	10.4	1	.61	.57	8.6	380.1	Dead (1)	--
6-11-99	229.3	11.3	1	.57	.33	9.5	373.0	27(1)	6-1
6-15-99	229.1	13.7	1	1.0	.9	12.3	837.1	Dead (1)	--
6-18-99	230.6	13.4	10	1.12	.7	11.7	1129.7	Dead (1)	--
								21(1)	6-16
								22 (2)	6-16
								23 (6)	6-15
6-21-99	235.5	10.1	3	1.01	.85	11.1	825.8	22 (1)	6-16
6-21-99	236.1	8.8	1	.83	.96	11.1	825.8	Dead (1)	--
								22 (2)	6-19
6-21-99	236.1	9.8	5	.83	.96	11.1	825.8	Dead (2)	--
								21 (3)	6-19
6-25-99	231	10.4	1	1.02	.84	10.6	860.1	Dead (1))	--
6-28-99	231	9.8	3	--	--	10.7	806.6	Dead(3)	--

Appendix 6. Year class, number captured, capture locations, fork length (cm), total length (cm), and weight (kg) of hatchery released juvenile sturgeon from the Kootenai River, Idaho, 1999.

Year class	No. captured	Capture rkm	Fork length (cm)	Total length (cm)	Weight (kg)
1990	1	215.7	69	82	2.25
1991	4	203.5	52-72	61-83	.95-2.7
	2	205.0	56.7-62.3	63.3-65.9	1.25-1.6
	3	215.7	55-61	62-72	1.05-1.6
	1	225.0	60.5	70	1.65
1992	1	227.0	66	80	1.7
	1	225.1	56	65	1
	1	225.0	55	65	1.1
	2	205.0	64.9-65.5	70.4-70.5	1.6-1.7
	3	203.5	61.5-66	71.5-75	1.55-1.9
1995	1	163.0	35.2	41.7	.24
	9	190.0	31-42	36-49	.15-.45
	1	195.7	50	57	.65
	6	203.5	35.5-43	42.5-49	.275-.5
	1	204.1	39	45	.35
	19	205.0	30.8-46.5	35-54.5	.125-.55
	2	224.6	36.5-37.4	41.3-41.5	.25-.345
	1	224.7	29.8	34.4	.155
	26	225.0	30-45.5	34-52.5	.15-.55
	9	225.1	33-44	38-52	.2-.45
	5	227.0	29.5-51	33.5-61	.1-1
	3	227.2	33-35	38-40.5	.15-.2
	4	227.3	30-34.5	34.5-56	.1-.2
	9	227.4	29-35.5	33-41	.15-.25
	16	227.5	31-45	36-52	.15-.35
	2	234.3	34.2-35	38.2-39	.16-.19
	1	234.4	37	42	.2
	2	244.4	29-42.6	32.8[a]	.055-.21
	8	244.5	23-43.1	33.3[a]	.099-.248
	1	244.6	33	38.8	.195

[a] Total length of the longest individual was not measured.

Appendix 7. Capture location, fork length (cm), total length (cm), weight, and year class of wild juvenile sturgeon captured in the Kootenai River, Idaho 1999.

Fish number	Capture rkm	Gear type	Fork length (cm)	Total length (cm)	Weight (kg)	Year class
5390	140.0	Gillnet	26.0	28.5	.10	1995
5384	140.0	Gillnet	56.0	64.5	1.10	1991
3251	203.7	Setline	95.0	109.0	6.25	1970
5380	215.7	Gillnet	37.0	41.0	.20	1993
5350	516.6	Setline	97.0	112.0	7.25	1978
5352	205.0	Gillnet	69.0	81.0	2.40	1990

Submitted by:	**Approved by:**
	IDAHO DEPARTMENT OF FISH AND GAME
Vaughn L. Paragamian Principal Fisheries Research Biologist	Virgil K. Moore, Chief Bureau of Fisheries
Gretchen Kruse Senior Fisheries Technician	Steve Yundt Fisheries Research Manager
Virginia Wakkinen Fisheries Technician	